Light Emitting Diodes: Technology Update

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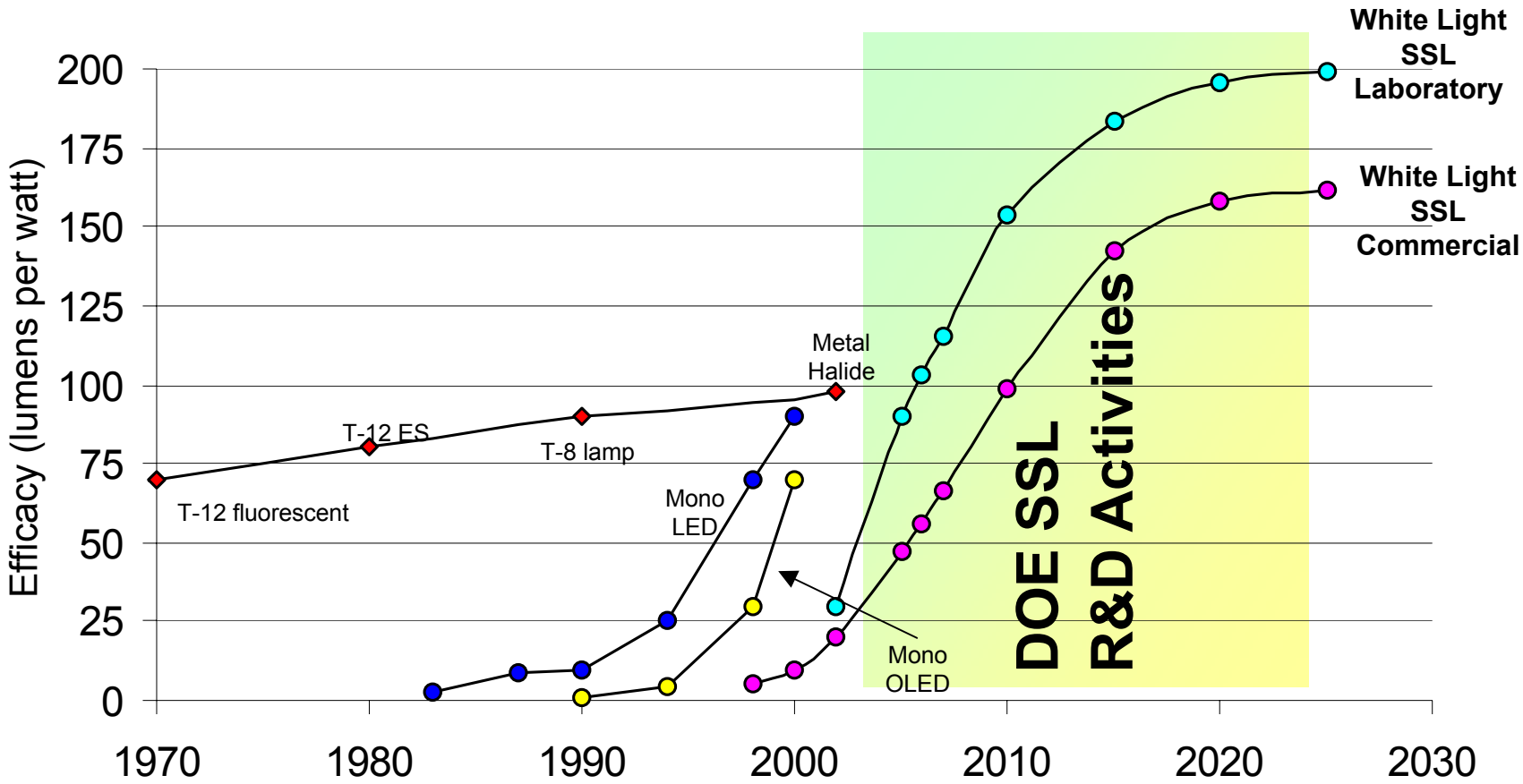
Cree, Inc.

Outline

- Update on LED technology for lighting
- Highlight technical challenges
- Review trends in efficiency and price
- Near-term niche applications

R&D Goals for White Light SSL



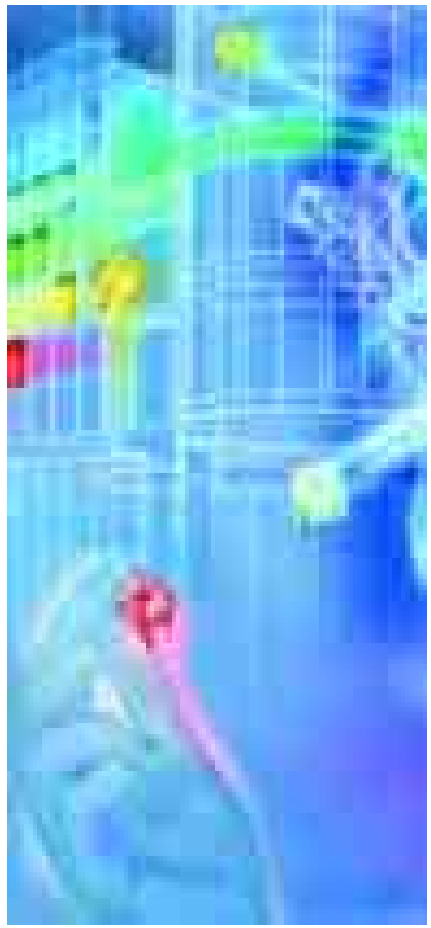
SSL Laboratory and Commercial Curves, revised September 2004

LED Packages

- High-brightness (HBLEDs)
- 5 mm/"through-hole"

White Light SSL Challenges

- Lifetime
  - lumen maintenance
  - thermal management
- Luminous efficacy
- Color quality
- Total luminous flux
- Cost
- Test procedures and standards



Color Quality Issues

- Correlated color temperature (CCT)
  - Color appearance of white light
  - High CCT sources look "cooler" and bluer
  - Low CCT sources look "warmer" and more yellow
  - Higher efficacy LEDs typically have high CCT
- Color consistency
  - Different color appearance within shipments of white LEDs
  - Color shifts over time with LED degradation
- Color rendering index (CRI)
  - Phosphors with more red improve CRI, but lower LPW

White LED Efficacy is Improving

- Cree, Inc. announced 70 lpw for the XLamp 7090 in development
- XLamp 7090 currently rated 45 lpw for 4500-8000K white
- Lumileds Luxeon I currently rated 45 lpw for 5500K white

However…

LED Efficacy in Practice

- Manufacturer data represents performance under laboratory conditions
  - Typically tested at 25 degrees C
  - Pulsed operation; not continuous
  - Actual performance depends on electrical, thermal design
- Higher efficacy LEDs have high CCT/low CRI
- Consumer products often use clusters of 5 mm LEDs
  - Lower efficacy ~ 15-20 lpw
  - Low wattage and low light output

Efficiency and Cost of White Light Sources

Source efficacy (2006)

- Incandescent (75W) ~13 lpw
- Fluorescent (T8) ~83 lpw
- HID (Metal Halide) ~100 lpw
- SSL (White LED) ~45 lpw

Normalized retail lamp price (2006)

- Incandescent (75W) ~0.60 $/klm
- Fluorescent (T8) ~0.73 $/klm
- HID (Metal Halide) ~1.27 $/klm
- SSL (White LED) ~50.00 $/klm

*manufacturer data

Research is improving SSL efficacy while decreasing price

Potential Near-Term Applications

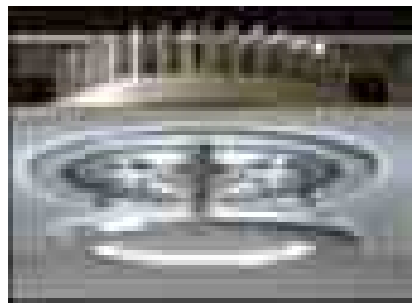
- Airplane reading lights
- Accent lights, focused light applications
- Task lights, desk lights
- Under cabinet
- Display cases, including refrigerated
- Elevators – vibration resistant, long life
- Architectural (hard to reach locations)

Potential Near-Term Applications

MR16s

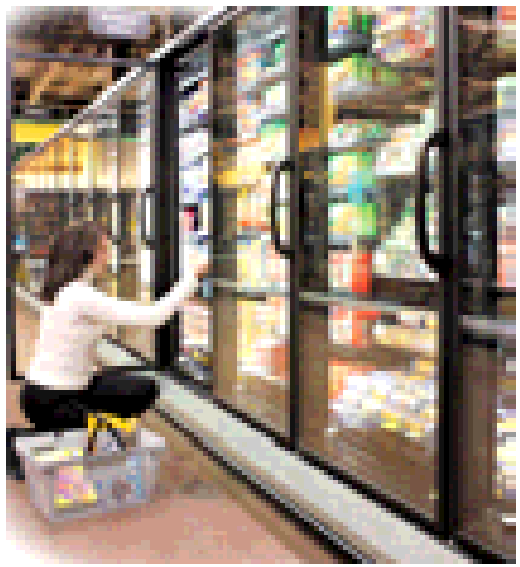
Color Kinetics

Elevator downlights



LRC

Refrigerated case lights



GELcore

Retail display

MAG-LED

Evaluating LED Products

Compare with most energy efficient lighting available for the application

- ❑ **Verify lumens per watt**
  - **Incandescent:** 12-15 lpw
  - **CFL:** 50 lpw
  - **LEDs:** ~20-45 lpw depending on specific LEDs used
- ❑ **Verify total light output**
  - **Product manufacturers often don't report it**
  - **Will the fixture/system provide the needed amount of light on the task?**
- ❑ **Calculate cost**
  - **Conventional (fluor., incand.):** $1/1000 lumens (klm)
  - **LEDs:** $50/klm
  - **LEDs on 24/7 or in hard to reach areas: potential cost savings on maintenance**
- ❑ **Assess need for special LED features (durability, accessibility)**
- ❑ **Check color**
  - **Bluer tones than fluorescents**
  - **Warmer tones less efficient**
- ❑ **Obtain a sample**

Sources of Information

- http://www.netl.doe.gov/ssl/faqs.htm
- Request to be on e-mail list for periodic updates
- Marc Ledbetter, Tel. 503-417-7557
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